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Agricultural Research

Scientists Seek Rangeland Sustainability

Rating Rangeland Health

Back in the 1930's, when USDA scientists first began monitoring rangeland conditions, it was commonly believed that vast acreages were good for little more than rattlesnakes, coyotes, and grazing cattle. Today, when rangelands accommodate more people and more uses than ever before, the stakes have been raised for rangeland science. Today, it's a high-priority research mission.

Rangeland science provides the fundamental knowledge that ensures U.S. rangelands can and will be maintained and conserved for future generations' use.

A little over half of all U.S. land—about 1.2 billion acres—is classified as rangeland. It encompasses all natural grasslands, savannas, shrublands, deserts, tundras, marshes, and meadows.

Rangelands are largely the result of limited precipitation. They are most often found in areas where the average annual precipitation is less than 30 inches per year—and vast expanses of rangeland receive 15 inches or less.

The current challenge facing users of American rangelands is managing multiple uses sustainably. For, when properly grazed, rangelands can repeatedly and without interruption provide people with food, fiber, and recreational activities.

Key to monitoring sustainability is measuring rangeland health. Recent legal mandates and a publication by the National Research Council call for new scientific tools and information to obtain such measurements.

This year, ARS scientists joined forces with five other federal agencies and two private organizations to develop these tools.

They are: USDA's Forest Service and the Soil Conservation Service; U.S. Department of the Interior's Bureau of Land Management and the National Biological Survey; and the U.S. Environmental Protection Agency, along with the Society for Range Management and the Western Regional Research Coordinating Committee composed of 40 western state land-grant colleges and universities.

The ARS team members are Dennis R. Child, ARS' national program leader for range research; Walter W. Heck, plant physiologist with the Air Quality-Plant Growth and Development Research Unit in Raleigh, North Carolina; Mark A. Weltz, hydrologist with the Southwest Watershed Research Center in Tucson, Arizona; and James A. Young, rangeland scientist with the ARS Conservation Biology of Rangelands Unit in Reno, Nevada.

For many years, rangelands were defined as lands supporting a natural vegetation cover of grasses, grasslike plants, or shrubs and were managed as natural ecosystems. Today, the classification has been expanded to include lands that support introduced (non-native) species, so long as they are managed as natural ecosystems.

It is difficult to come up with a practical evaluation system that works in the many ecosystems classified as rangeland. Sand dunes and sagebrush are perfectly healthy and normal in Nevada's high deserts, but that can't be applied as a standard in Florida's grasslands.

Research directions are changing, team members agree. But yesterday's work may be used to feed today's data-driven computer models.

"At the first meeting, held in May, we looked at the information we can keep, such as erosion and watershed information coming from the Revised Universal Soil Loss Equation and the Water Erosion Prediction Project. Everyone agreed on the importance of holding the soil in place on the land. Once we've lost the soil, management options are limited," Weltz says.

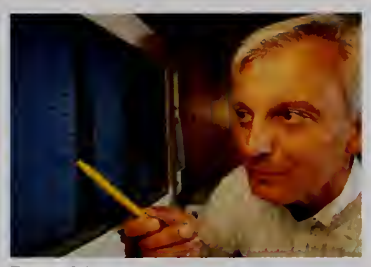
"We also found areas that need work. These include learning how to deal with natural phenomena, such as severe flooding that occurs only once a century, or the natural erosion found in the South Dakota Badlands," he says.

"We're reevaluating the scientific basis of range management," says Young. "The new system will be based on sustainability of the rangeland, but will include human activity as a given."

Kathryn Barry Stelljes
ARS Information Staff

Agricultural Research

Cover: Agricultural Research Service scientists are helping users of American rangelands meet the challenge of managing multiple uses sustainably. Bison photo by Jack Dykinga. (K5680-1)



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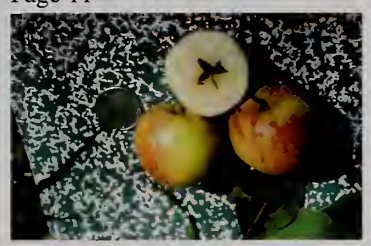

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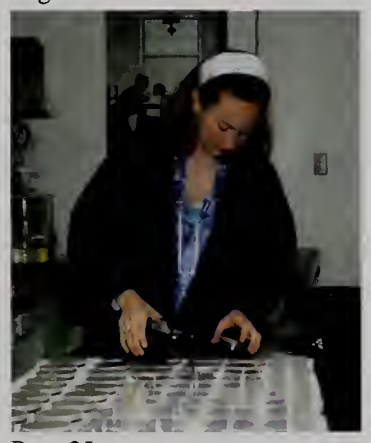

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Science at Home on the Range

"We remained...to enjoy the delightful prospect of the plain, which spreads itself out at a great distance, enlivened by large herds of buffalo..."

Meriwether Lewis and William Clark, 1805

By the time Harold Heady started studying the range, this view had changed to a dusty landscape withering under a great drought.

"In 1938, I was riding a horse across my ranch in southern Idaho, and I didn't see a perennial grass anywhere in half a day. It looked like the grass was gone," says Heady, a well-known range ecologist retired from the University of California.

Ten years ago, he returned to the same area in Idaho. "Walking through the sagebrush, I spotted several native species of wheatgrass and brome within half a mile," he says.

Rod Heitschmidt says the return of the grasses is not an accident.

"The improved ecological condition of rangeland is a product of research on how grazing affects the land and application of that research by ranchers and land managers." Heitschmidt is a rangeland scientist at the ARS Fort Keogh Livestock and Range Research Laboratory in Miles City, Montana.

For example, Heitschmidt says, USDA scientists in Miles City and Nunn, Colorado, developed stocking rates and forage use guidelines in the 1930's that became the standard for grazing cattle on arid and semiarid lands. "These standards helped prevent the environmental degradation that was common before scientists and ranchers understood the hazards of overgrazing," he says.

ARS rangeland scientists Jonathan D. Hanson and Richard H. Hart have developed computer programs now being used by ranchers, land managers, and researchers to predict the effects of grazing practices and stocking rates on the rangeland plant community.

They are called SPUR (Simulation of Production and Utilization of Rangelands), SMART (Simple Model to Assess Range Technology), and STEERISK, which is a spreadsheet for calculating average returns and financial risks under different grazing schemes. These models help livestock producers protect the environment and maximize profitability from their herds.

But today there are new questions about range condition, fueled by debates over use of public lands and potential global climate and environmental changes.

"Ranchers are accused of hurting the rangeland, but we're being challenged under perceptions, not facts," says Jim Courtney, a Montana rancher who raises cattle on 20,000 acres of public and private land. "We need science to tell us more about how grazing really affects the land."

For instance, what constitutes optimum health for rangeland? How do plants recover from overgrazing and drought? Can problem areas be restored and future damage prevented? How does grazing by livestock and wildlife fit in?

ARS scientists at 25 locations nationwide are working to answer these and other questions.

Measuring—or even defining—rangeland health is far more difficult than most people realize.

KEITH WELLER

To determine growth activity, rangeland scientist Marshall Haferkamp measures water status of a western wheatgrass plant. (K5683-1)

KEITH WELLER

Hereford cattle on ARS' Fort Keogh Livestock and Range Research Laboratory near Miles City, Montana. (K5685-1)

KEITH WELLER

Technician Cheryl Murphy collects runoff water from lysimeters at Fort Keogh research site. (K5682-1)

"Biologically, it's chaotic. There may be as many as 20,000 variables that interact in perhaps a billion different ways," says Kris M. Havstad, a rangeland scientist in the ARS Range Management Research Unit at Las Cruces, New Mexico.

And Havstad says rangeland data can be interpreted more than one way. "We have data from eight decades at the Jornada Experimental Range near Las Cruces. These data indicate to some people that current rangeland conditions are the best ever; yet other people say the same data show that rangelands are unhealthy."

Part of the problem is the breadth of the term "rangeland."

While Western movies conjure up images of sagebrush and cactus, rangelands include all natural grasslands, savannas, and shrublands, as well as, deserts, tundras, marshes, and meadows. About half of U.S. land—mostly in 19 western states—and 60 percent of lands worldwide are classified as rangeland.

"We have a real need for ecological measuring sticks that reflect the condition of or change in the ecosystem as a whole, not just superficial indicators like plant species shifts," Havstad adds.

To develop such tools, ARS scientists are studying the basic biology of experimental ranges—including 190,000 acres at the Jornada, 55,000 acres at Fort Keogh, 16,000 acres at the ARS Central Plains Experimental Range near Nunn, Colorado, and 3,000 acres at the ARS High Plains Grasslands Research Station in Cheyenne, Wyoming. These living laboratories have provided decades of information on the effects of weather and grazing and other management practices on rangeland animals, plants, soil, and water.

State-of-the-art computer models will also help. Jornada scientists, in cooperation with New Mexico State University and the U.S. Department of Defense, are now modifying programs that were used during the Gulf War to integrate troop movement and topography.

This approach will replace simpler models that have worked for crop production. Predicting yields of a single crop, such as wheat growing with either rainfall or irrigation, is much easier than predicting yields of more than 600 plant species found on rangelands that get scant precipitation.

The new models will let scientists watch the rangeland over time, via color images viewed like slow-motion photography on a computer screen. The final step will be to link the computer program to digital information that satellites such as SPOT and Landsat provide.

Then ecologists and other researchers will be able to view potential range changes under various scenarios—like prolonged drought or specific grazing management programs.

Researchers at Las Cruces are also helping the U.S. Environmental Protection Agency (EPA) evaluate

JACK DYKINGA

Software engineer Kerry Williamson (left) and rangeland scientist Kris Havstad examine computer imaging of a select plot that reflects Jornada range plant growth in 1977. (K5670-1)

New models will let scientists watch the rangeland over time, via color images viewed like slow-motion photography on a computer screen.

indicators of natural and human-caused stresses on western rangeland.

"What causes rangeland to change from healthy to unhealthy, or the reverse, is usually from a variety of contributing factors," says Walter Whitford, a senior EPA ecologist temporarily located at Las Cruces. "Some are natural factors such as drought and fires started by lightening; others are induced by humans, like overgrazing.

"These factors are now being separated out to identify the importance of each," says Whitford. "For example, drought and overgrazing have historically occurred at the same time. But we still do not know which causes the greater long-term damage."

A new joint research project, funded in 1993 for 5 years under the EPA's Environmental Monitoring Assessment Program, will try to answer these questions. The results of the study will help ranchers and other land use managers sustain their land.

The interactions of drought and grazing are also the focus of research at Miles City.

ARS scientists at Fort Keogh have developed a motor-driven rainout shelter—a "roof on wheels"—to answer questions about the health of Northern Great Plains rangeland.

For this 2-year study, scientists installed 12 lysimeters. Each consists of a 15- by 30-foot block of native soil and vegetation, surrounded on all four sides by a 6-inch-wide by 7-foot-deep ditch. The ditches are filled with spray-on insulating foam.

"These containers effectively seal the native soil from its surroundings, except at the top," Heitschmidt says. A natural clay layer about 3 feet below the surface prevents water from infiltrating downward. Runoff is collected and pumped into a tank for measurement.

When it starts to rain, a sensor on the rainout shelter triggers the shelter to cover half of the lysimeters so that they receive no water.

"When it quits raining, the shelter moves off the lysimeters. So we have six in a simulated drought condition and six with normal rainfall," Heitschmidt says.

To bring in the grazing component, four of each set of six lysimeters (drought vs. normal rainfall) were grazed by sheep in the spring and summer of 1994. Next year, two of the four grazed areas will rest, and the other two will be grazed again.

By looking at as many characteristics of plants in the lysimeters as possible—such as root growth, seed germination, tiller growth, water potential, and soil structure—Heitschmidt says they should get a good idea of the different effects of drought and grazing.

"We believe that grazing during drought doesn't affect long-term productivity, but we suspect there may be effects if you graze immediately after drought," says

"Grazed lands seem to be healthier than rangeland fenced to keep cattle off. The grazed areas produce more forage and have less standing dead plant material."

Gerald Schuman
ARS soil scientist

JACK DYKINGA

On the Jornada Experimental Range, ARS animal scientist Rick Estell (left) and undergraduate student Antonio Garcia trap volatile chemicals emitted from tarbush leaves. These odors may give clues to why animals eat some plants and not others. (K5671-1)

Heitschmidt. His reasoning stems from the migrations of bison, the largest natural prairie grazers.

"When there was a drought, the bison either migrated out of the area or died. Once a drought was over, grazing would be light while the bison population built back up," he says. "If research results confirm this suspicion, both ranchers and the environment might benefit by resting the land after a drought."

Research at the High Plains Grasslands Research Station near Cheyenne also reveals the importance of grazing in the rangeland ecosystem.

Richard Hart and ARS soil scientist Gerald E. Schuman are comparing grazed with ungrazed native rangeland.

Within a 520-acre plot, two fenced areas have been protected from livestock grazing for over 40 years. The remaining pastures have been grazed at three intensities and under three grazing strategies.

The scientists are assessing the soil quality of each area by measuring the amounts of soil organic nitrogen, soil organic carbon, soil carbon respiration, and nitrogen mineralization.

"Grazed lands seem to be healthier than rangeland fenced to keep cattle off. The grazed areas produce more forage and have less standing dead plant material than the ungrazed areas," Schuman says.

To understand the bigger picture of rangeland health, ARS researchers are also participating in far-reaching studies, such as the National Science Foundation's Long-Term Ecological Research Program (LTER).

The Jornada and Central Plains Experimental Range are 2 of 18 U.S. sites included in the study, which strives to identify general ecological changes that occur over a long time. In the next few years, scientists in the study will design and document long-term experiments for use by future generations.

One of the program's basic premises is that rangeland health is directly related to the distribution of soil resources. The Jornada will help scientists understand how lands become desertlike.

Scientists from Duke University, Dartmouth College, the U.S. Geological Survey, the State University of New York at Buffalo, University of New Mexico, and New Mexico State University are collecting basic information on the Jornada's ecosystems. For example, one study is measuring nitrogen cycling in and around tarbush, an important shrub on Jornada rangeland.

At the Central Plains Experimental Range, similar studies are examining how grazing affects nitrogen and other nutrients in soil and range plants. These studies will also help ranchers understand what's happening on the land.

"Having thorough knowledge of the structure and function of delicate

ecosystems will help us fill niches without destroying the land—like knowing exactly where to place my cows so they will not harm, and may even improve, the land," says Jim Winder, principal owner of Beck Land and Cattle Company in Nutt, New Mexico. The company currently ranches about 60 square miles of land, half of which is leased from the government.

"Our need for this information is not merely because of financial considerations. It's important to find methods that are also socially acceptable and environmentally sound," he says.—By **Kathryn Barry Stelljes**, ARS. **Dennis Senft,** ARS, contributed to this article.

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KEITH WELLER

Rangeland scientists Rod Heitschmidt (left) and Mike Karl (middle) and assistant Erik Eneboe examine aerial photographs of the 55,000-acre Fort Keogh location, while research assistants harvest forage within rainout-shelter lysimeters. (K5681-l)

KEITH WELLER

Using a soil water probe, rangeland scientist Mike Karl conducts a weekly measurement of soil water content in an ungrazed control-plot lysimeter. (K5684-1)

Planting With a Feather-Light Touch

A handy attachment for seed planting machines could boost seedling survival. The device, bolted to a planter that's hooked to a tractor's tool bar frame, ensures that seeds get planted at just the right depth. At the same time, it allows growers to select the correct pressure for compacting the soil.

The hydraulically controlled tool is the only one of its kind that enables growers to independently adjust controls for these two separate functions—planting depth and pressure, says Lyle Carter, an ARS agricultural engineer who invented the device.

"It can give you as much force as you need to cut a slot for seeds in hard, dry soil," he says. "But it can be feather-light—if necessary—when covering the newly planted seed."

The separate controls, easily preset by turning a depth rod and a spool, allow successful seeding throughout a farm, from moist, yielding valley soils to dry hillsides.

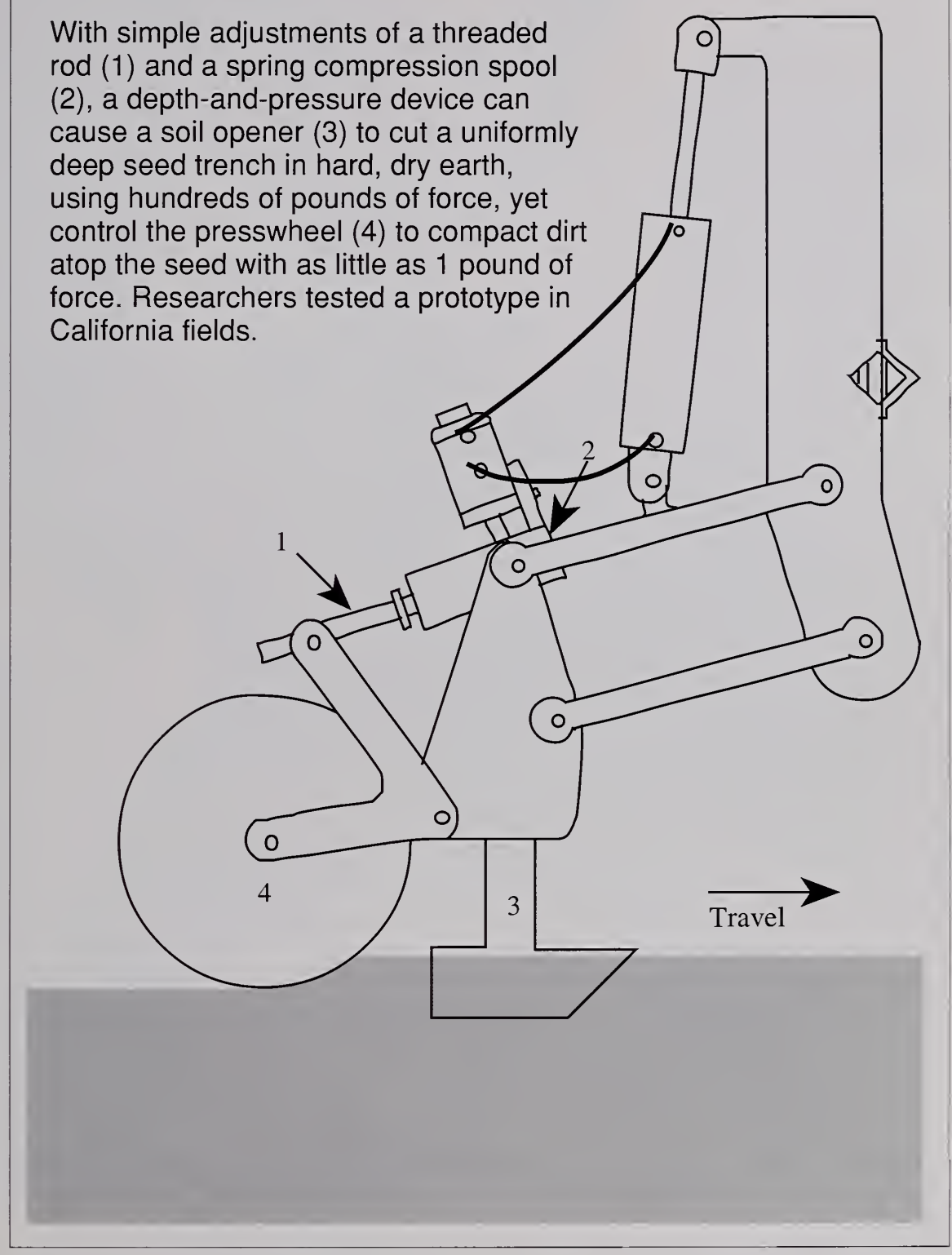
The implement's hydraulics readjust depth and pressure to the preset levels as the tractor moves across the field. Conventional depth-control devices, in contrast, are typically set for the toughest soils and can't be easily readjusted on the go; on soft soil, they might set seeds too deep and compact the seed trench too firmly.

Emerging seedlings that are buried too deep may die before they reach sunlight, because they use up all their food reserves.

Carter says his invention "might reduce the number of specialized seeders that farmers today must buy in order to accommodate the various planting depth requirements of different crops."

The invention could also be used with tillers, cultivators, plows, and fertilizer and pesticide applicators, to increase their precision.—By **Marcia Wood,** ARS.

With simple adjustments of a threaded rod (1) and a spring compression spool (2), a depth-and-pressure device can cause a soil opener (3) to cut a uniformly deep seed trench in hard, dry earth, using hundreds of pounds of force, yet control the presswheel (4) to compact dirt atop the seed with as little as 1 pound of force. Researchers tested a prototype in California fields.



For further information on Patent. No. 5,234,060, "Pressure and Depth Control in Agricultural Implement," *contact Lyle M. Carter, USDA-ARS Cotton Research Station, 17053 Shafter Ave., Shafter, CA 93263; phone (805) 746-6391, fax (805) 746-1619.* ◆

Genome Mapping Points the Way

Expanded database will speed improvement of cattle, swine, and sheep.

A new era of dramatic advances in farm animal breeding is expected to follow the release earlier this year of the world's first "maps" of cattle and swine genetic makeup.

Since the first stages of the interactive genomic databases went on-line in April 1994, ARS chemist Craig W. Beattie says, "We've shared a tremendous amount of information with scientists all over the world."

Information that will further hasten map development is currently being shared through agreements with the United Kingdom and New Zealand. The latter effort on combining markers and other information involves the sheep genome.

As cattle and swine genome maps are being expanded and refined, a map for sheep is also under development for release next year, says Beattie, team leader of the project at the Roman L. Hruska U.S. Meat Animal Research Center (MARC) in Clay Center, Nebraska.

A genome describes one set of an individual's chromosomes with the genes they contain. This information forms a basis for new technology to eventually provide consumers with improved quality.

Genome maps are expected to help scientists and the livestock industry in their efforts to:

- Improve the accuracy and shorten the time required to make genetic improvement for economically important traits in livestock
- Develop animals resistant to disease, parasites, and foodborne pathogens such as *Salmonella*
- Develop strategies for preserving animal germplasm diversity
- Provide a higher quality, safer product to consumers.

Biological Cartography

To develop genetic linkage maps, scientists first extract DNA from cells—often blood or semen—from a group of animals made up of defined families or pedigrees.

Then they use a process called polymerase chain reaction (PCR) to amplify minute amounts of a marker and a process called electrophoresis to separate it into its alleles, or different forms. As researchers identify the alleles that are most closely associated with inheritance of a particular trait, they conclude that a gene or genes controlling the trait lies in or near the allele. The heritability of marker patterns—allelic variations—makes them useful in identifying or selecting breeding animals.

In January 1992, MARC scientists began their intensive project to link hundreds of genetic markers—map objects such as genes and anonymous DNA sequences—along each chromosome of cattle, swine, and sheep.

The program mainly involves defining the location of markers and identifying which of these markers are closely associated with specific traits of economic importance to the livestock industry.

Ultimately, identification of the locations (loci) of genes or groups of genes that regulate traits like meat quality, lean growth, reproductive efficiency, and disease resistance will allow rapid and improved selection of animals expressing these traits.

As additional markers are identified, the task of associating genes with specific traits and developing marker-assisted selection programs becomes easier.

Moreover, Beattie says, having maps saturated with markers helps researchers begin to concentrate their studies on specific genes. That's an essential step toward understanding how these genes regulate traits.

Saturation of genome maps with markers is taking place rapidly as scientists link markers to pairs of chromosomes. But there's much still to be done, as the chromosomes are vastly complex double-stranded helixes of DNA comprising billions of chemical components called nucleotides, or bases, that are chemically joined together.

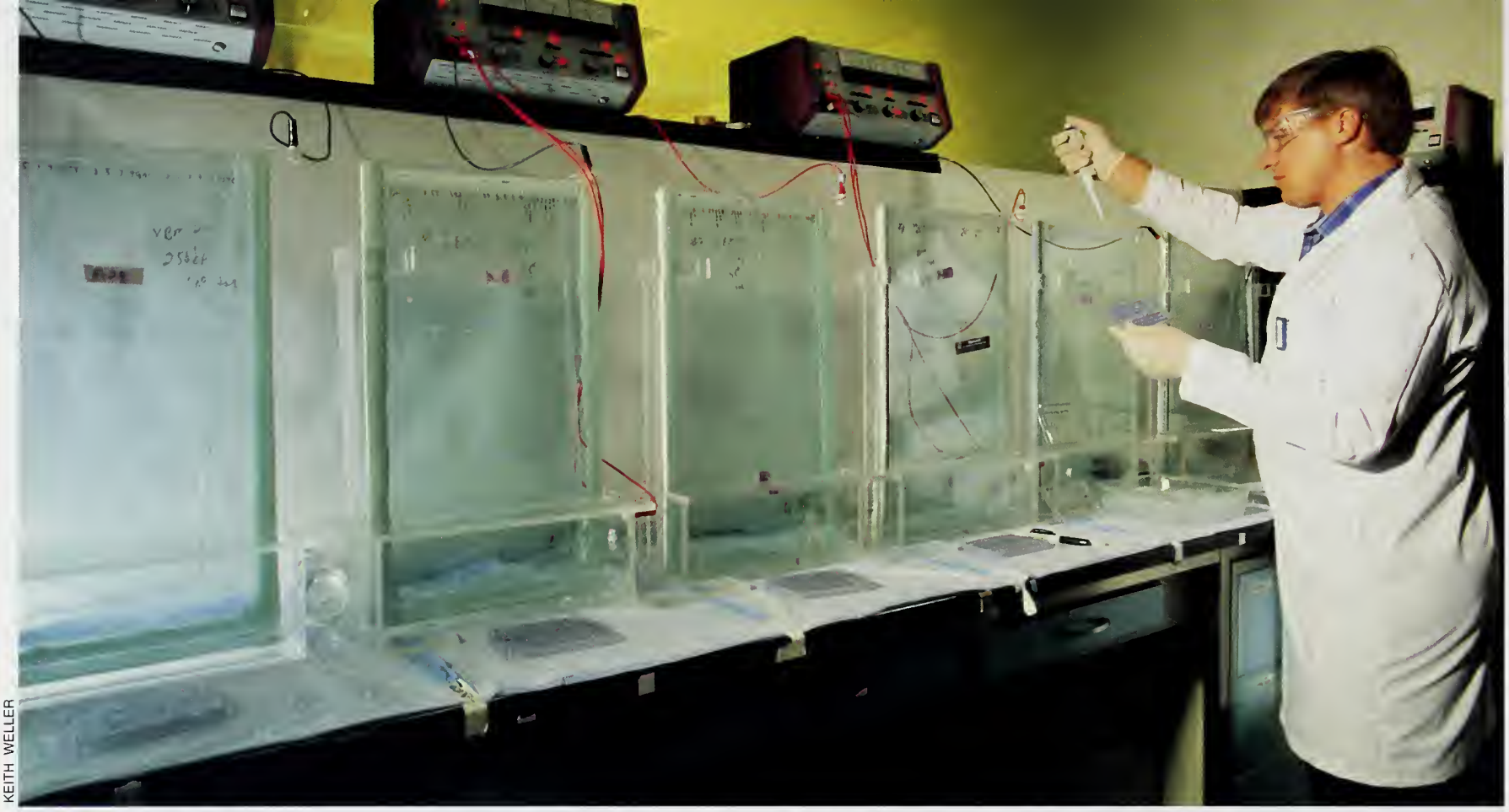
Cattle have 30 pairs of chromosomes; swine, 19; and sheep, 27. Distances between markers along the chromosomes are generally estimated in units called centimorgans (cM). One cM equals 1 million bases.

Initially, markers flanking genes within 5 cM should prove useful for selective breeding purposes, Beattie

KEITH WELLER

Chemist Craig Beattie views sections of swine genetic linkage map on an interactive database for use by scientists worldwide. (K5668-10)

Geneticist Gary Rohrer and student intern Aleceia McFadden enter genotypic data into the MARC genome database. Photo by Keith Weller. (K5668-11)



KEITH WELLER

Physiologist Steven Kappes loads genotypic samples on a polyacrylamide gel to be separated by size of DNA fragment. (K5669-3)

says. When the cattle and swine maps were first published, more than 85 percent of the markers on each map were pinpointed at locations less than 10 to 15 cM apart.

Now, with the map further saturated with markers, the scientists are rapidly expanding breeding experiments to identify traits controlled by genes in the vicinity of the markers.

The studies involve cattle, swine, and sheep families made up of several breeds.

The combination of scientific expertise and sufficient numbers of animals of widely varied genetic types at MARC makes the facility inherently well suited for rapid progress in livestock genome mapping studies, says Dan Laster, director of the center.

Advances can result without waiting for, or depending on, progress in transgenic—genetic engineering—technology, he says.

Laster also notes that technology and informational spinoffs from the human genome mapping effort made similar work on livestock possible.

The center is now providing access to these genomic maps for cattle and swine in a unique, interactive database for use by scientists in federal, state, and commercial research facilities. Routinely updated as more information becomes available, the database will eventually contain maps for all three species, as well as performance data.

It's through a climate of cooperation among researchers in many organizations that the rapid scientific advances of today are possible, Laster says. Technology related to the genome project will help ensure U.S. agriculture's competitiveness in world markets.

One of the goals is for MARC scientists to use the maps to develop technology for the livestock industry.

As these technologies develop in the United States, livestock producers and meat processors could be aided by new service industries—such as genetic diagnostic laboratories—in endeavors to improve production efficiency and satisfy consumer desires for lean, high-quality, safe products.

As scientists refine the genetic linkage map for each species, they can develop diagnostic probes to tell whether desirable or undesirable genes are carried by an individual animal or by a group or family of animals.

Within the next few years, marker-assisted selection of breeding animals is expected to become the first major use of the data in livestock genome maps, says Laster. It is already being used to a limited extent by the dairy industry. Through this technology, cattle that will grow up to have favorable or unfavorable traits can be identified while still young.

Larry V. Cundiff, who heads the MARC Breeding and Genetics Research Unit, says precise genetic selection may lead to expanded use of specific characteristics from individual breeds of cattle. For example, some breeds have genetic advantages that impart tenderness to the meat, along with other, disadvantageous traits, such as slow growth rate or excessive fatness.

"When we can identify desirable and undesirable genes in individual animals, we can more freely use breeds for the traits they bring to a crossbreeding system," Cundiff says.

—By **Ben Hardin,** ARS.

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Walking for Exercise

A mile a day helps delay bone loss.

Going that extra mile each day doesn't only help one succeed in life. It also helps keep women's bones stronger as they age, reducing the chance of fractures late in life, according to a new study of women's walking habits.

Study leader Elizabeth Krall says walking is often recommended as a way to help protect against loss of bone density—or how closely calcium and other minerals that constitute the bulk of bone are packed together.

"Compared to other types of exercise," she says, "walking is perhaps the safest and most appropriate activity for a wide range of the population, including the elderly."

Some studies have shown that women who begin a walking program can reduce bone loss during and after menopause. [See "Walking—Backmending Exercise for Women," *Agricultural Research,* May 1991, p. 24.] And other studies have found a link between women's bone density and their lifelong physical activity habits.

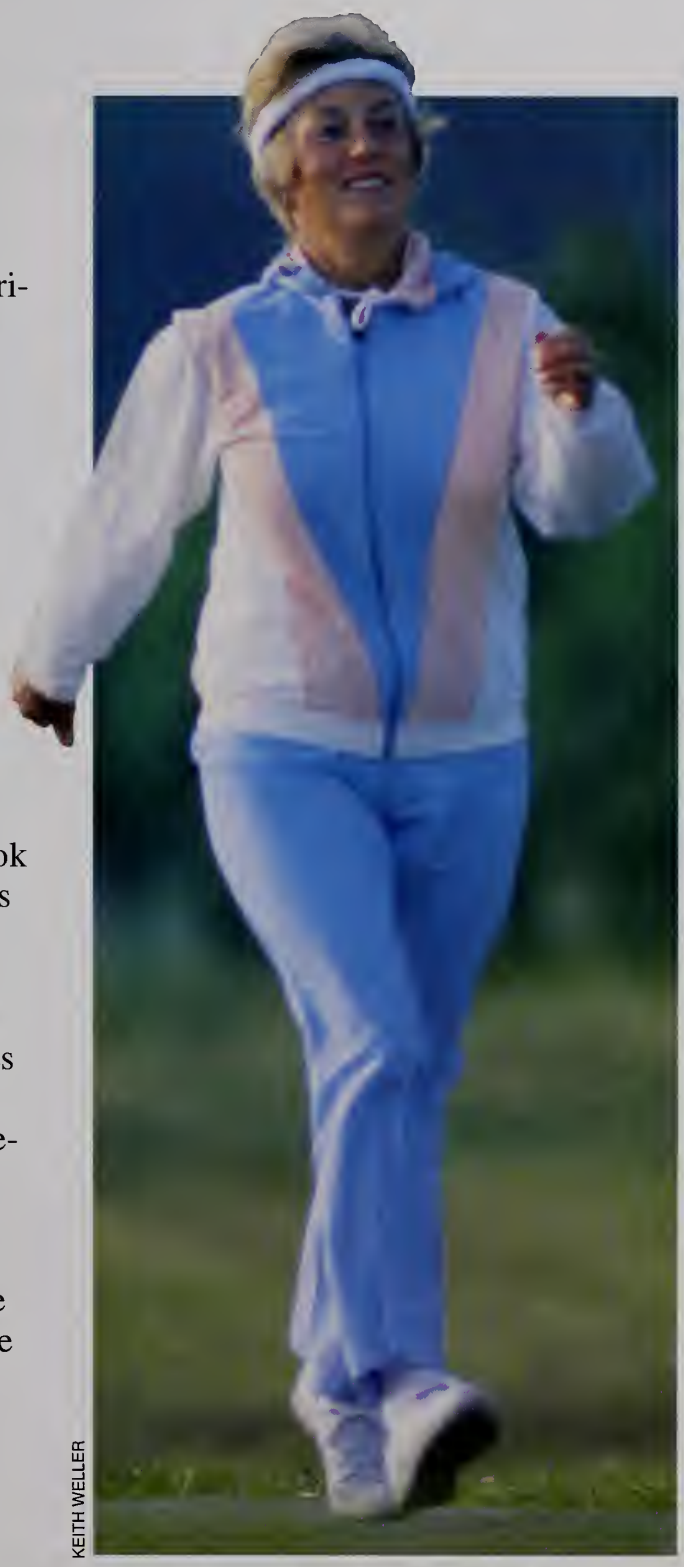
But most such studies did not look at walking per se, says Krall, who is at ARS' Jean Mayer Human Nutrition Research Center on Aging at Tufts University in Boston. So she and colleague Bess Dawson-Hughes wanted to know how walking itself is related to bone density at fracture-prone sites and whether it helps to slow the rate of bone loss.

Preventing or postponing bone loss can have a major impact on the nation's pocketbook—as well as the quality of life for older people.

The National Osteoporosis Foundation estimates that half of American women over age 50 and three quarters of those over age 75 have significant bone loss.

Fractures resulting from bone thinning currently cost between $10 and $18 billion annually, according to the foundation. And most of that is paid by Medicare.

In the new study, Krall and Dawson-Hughes measured bone densities in 238 healthy, post-menopausal Caucasian women three times during a year-long study.



KEITH WELLER

Walking, occupational health nurse Nancy Thrush agrees, helps maintain healthy bones. (K5120-5)

Krall also took detailed histories of their physical activities from age 14 and separated out the walking data from other activities, such as sports or gardening.

The women who had habitually walked more than 7.5 miles per week—or about 1 mile a day—had 4 percent more bone density in the trunk and 7 percent more in the leg bones than those who had walked less than a mile per week, she says. The walkers also had a slower rate of bone loss in their legs during the year of measurements.

Normally, says Krall, during the 5 years surrounding menopause, women lose an estimated 3 to 6 percent of their bone density each year. That slows down to about 1 percent later on.

Most of the women in the study, whose average age was 62, were well past menopause. So based on their measurements, says Krall, "walkers have 4 to 7 years' more worth of bone in reserve than nonwalkers."

Walking in and of itself will not prevent osteoporosis altogether, she says, but it appears to help delay its onset in women.

And osteoporosis isn't limited to women. Although men begin with higher bone density than women—ranging from about 15 to 30 percent more, depending on the body site—their bones also thin with aging. As men live to older ages, she notes, osteoporosis will become still more of a health problem.—By **Judy McBride,** ARS.

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SCOTT BAUER

Probing the Soils of the Frozen North

The Frost Crew has the chilling task of monitoring snow and frost all winter in Minnesota. They are the underground weather observers of the U.S. Department of Agriculture.

The Frost Crew enjoys its work around cornfields on the 120-acre Swan Lake Research Farm until about December. After that, the snow is there to stay, and several layers of clothing—along with 4-wheel-drive pickups and tractor-mounted snowblowers and shovels—are often essential.

While the temperature in November is usually below freezing, the days can be sunny and relatively snowless. But the Frost Crew is wary, after 2 years of cooler-than-usual winters and more than the usual amount of snow.

Frost Crew is the local name for a team of USDA researchers who are in their 13th winter of studying effects of the frost/thaw cycle on soil structure and the movement of soil water and farm chemicals toward groundwater.

The current crew leader is soil scientist James A. Staricka, who is with the ARS' North Central Soil Conservation Research Laboratory in Morris, Minnesota, near Swan Lake.

The newest member of the team, soil scientist Brenton S. Sharratt, transferred from Alaska, where he conducted subarctic research.

To encourage research, a private organization, the Barnes-Aastad Soil and Water Conservation Research Association, bought a farm on the west edge of Swan Lake and leases it to the lab for a nominal fee.

The difficulty of working outdoors in northern winters is one of the factors hindering scientific knowledge about water and chemical movement through the freeze/thaw cycles, Staricka says.

Another limiting factor has been the assumption that soil is inert during the winter.

In fact, however, a very dynamic freezing and thawing cycle operates below the deep snows. It can affect whether fertilizers and pesticides applied the previous season will contaminate groundwater in the spring. It also affects the availability of water and fertilizer to plants.

SCOTT BAUER

Soil scientist Jim Staricka (left) and technician Scott Larson use a tractor-mounted hydraulic probe to obtain a core of frozen soil. (K5417-5)

Since 20 to 25 percent of the nitrogen fertilizer used in the western Corn Belt is applied in the fall, what happens underground during the winter has an effect on a substantial amount of nitrogen fertilizer.

Staricka describes a downward-moving "freezing front"—the location in the soil where water changes to ice. Like drying, freezing sucks water up from underlying soil. This upward movement of water may also move small amounts of chemicals upward a short distance.

"Water can move up or down through frozen ground by passing through wormholes and cracks and by merging with a thin film of water coating soil particles. Because of a chemical reaction with the soil, this film of water doesn't freeze until well below 32°F," Staricka says. "And this water can carry pesticides and nitrate-nitrogen from fertilizer and natural sources. Such contaminants are pushed out into unfrozen water as ice crystallizes."

In cool climates with moderate rainfall, like Minnesota's, any water held above the freezing front can help give crops a head start in the spring and serve as a reservoir in the event of drought. But, Staricka says, in warmer, drier climates to the west and south, water held in the top 4 inches of bare soil is likely to evaporate.

During cold winters, the freezing front descends rapidly and may reach a depth of 5 to 7 feet by late February. During warm winters, the front moves slower and may reach only 2 to 3 feet down. After late February, the soil begins to thaw.

Soil freezing is not as deep or as fast where heavy snow insulates the ground. It is also not as deep in wet soils, which slow the freezing front. And the amount of cornstalks left on the surface after harvest can cause the frost layer to be shallower. The crop residue, which has an insulating effect of its own, does even more when it traps snow.

Then Comes the Thaw

In the spring, the snow generally melts before the soil begins to thaw. On relatively flat ground, the snowmelt stays on top of the soil, above the ice layer. On sloping land, such as the sides of the prairie pothole depressions common in central

Physical science aide Lynette Howe uses a frost tube to measure how deep the soil has frozen. (K5416-9)

Minnesota, the water flows downhill on or just under the soil surface, on top of the frozen layer—where the concentration of applied chemicals is likely to be greatest.

These subtle depressions occur on lowland of rolling terrain and vary greatly in size, from a couple of hundred feet to 2 acres or so. More obvious when wet, the natural low spots are partially and intermittently filled with water during wet periods, as in springtime.

ARS soil scientist John Daniel, a former Frost Crew member now engaged in water quality research at Durant, Oklahoma, says he and the crew found that snowmelt may flow from upland areas into shallow groundwater below the potholes. It can raise the water table under these potholes or other depressions as much as 6 feet in a week, as shown by water table measurements taken at each of 15 test wells scattered around the Swan Lake farm. The crew takes these measurements once a week during winter and three times a week during spring. They also sample the wells for chemicals once a month, year-round.

Daniel says he and the crew found positive effects from snowmelt: "It can dilute concentrations of nitrate that have built up in shallow groundwater over winter," he says.

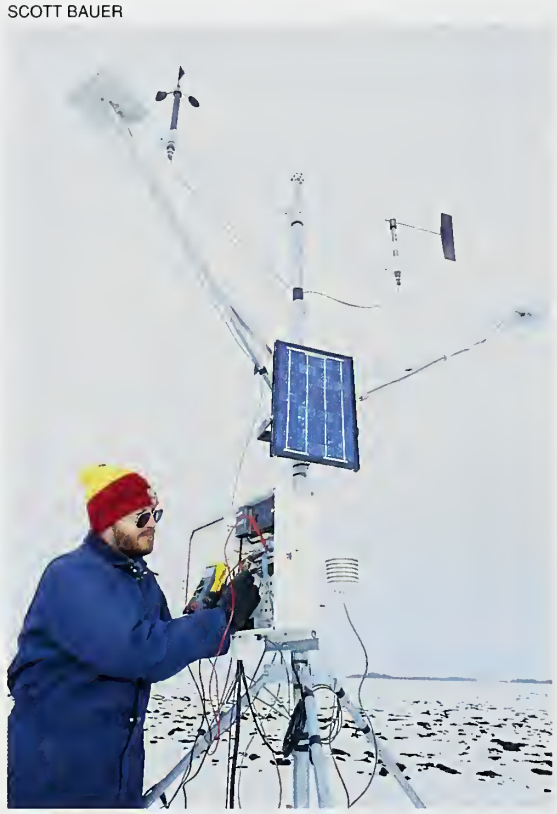
But soil made soupy by the trapped snowmelt can render farm fields uncrossable—even with a 4-wheel-drive vehicle—delaying spring planting for up to a month.

When the spring thaw eventually reaches completely through the frozen soil layer, water from the melting of 5 months of accumulated snow on the surface filters down through the soil another foot or so, in a matter of just a few days.

"This explains why soggy fields dry so quickly," Staricka says. "The spring thaw deposits pesticides and nitrate-nitrogen at the 3- to 5-foot-deep level."

To monitor the complex cycle, the crew stabs frost tubes into cornfields each November, penetrating 5 feet into the soil and leaving 1-1/2 feet exposed. The tube serves as a ruler to measure frost and snow depth. Two winters ago, the crew had to shovel drifts of up to 3 feet of snow—just to find the tubes.

SCOTT BAUER



Soil scientist Jim Staricka checks the operation of an automated weather station. (K5415-5)

The crew uses time domain reflectometry to monitor soil moisture; telephone companies use a variation of this relatively new technology to find breaks in underground cables. With it, electric cables are connected to sets of rods placed at depths of from 1 inch to 5 feet below the surface of the field. Electric signals are sent down a cable and through a set of rods—each spaced 2 inches apart—and the speed of the returning echo tells the amount of unfrozen water present, on an hourly basis.

The crew checks the recorded readings once a week during the winter. To measure frozen as well as unfrozen soil water, they insert a neutron moisture probe into the soil. They use a hydraulic device to force soil core tubes down 5 feet or more to collect samples three times during the winter and once after the spring thaw. They analyze the samples for pesticide and fertilizer chemicals.

Staricka says the freezing and thaw cycle can expand soil cracks and wormholes, helping to open up compacted soil.

"But it can also make soil more erodible, increasing surface water pollution from both the sediment and any farm chemicals that may have adhered to the sediment particles.

"The cycle influences the effectiveness of tillage practices such as the no-till practice of leaving crop residue on the soil surface, usually to a farmer's benefit. In turn, we are looking for ways farmers can manipulate the cycle by adjusting tillage and other practices."

Based on the data collected, Staricka recommends that farmers sample their soil for nitrate-nitrogen each spring, rather than fall, and that they go down to 5 feet, instead of the usual 1 foot.

"That's where the nutrients end up when the spring flush comes, and corn roots can reach these nutrients," he says. By sampling deeper, farmers can avoid applying too much fertilizer.—By **Don Comis,** ARS.

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John Daniel is in the USDA-ARS Water Quality Research Unit, Durant, OK 74702; phone (405) 924-5066, fax (405) 924-5307. ◆

What Makes Tortillas and Tacos Taste So Good?

The hearty flavor of corn flour products like tortillas and taco shells is largely the work of a natural compound not previously identified in these foods, ARS scientists report.

Ronald G. Buttery and Louisa C. Ling have pinpointed 2-amino-acetophenone as key to flavor and aroma of yellow corn tortilla flour. The team, working at the ARS Western Regional Research Center, Albany, California, was the first to discover the compound's importance to the flavor of this product.

Makers of tortillas and snack items such as tortilla chips could use the new results to check the quality of their products and perhaps to further boost the flavor of these foods. Too, they could check new, corn-flour-based products for the amount of flavor compound that they contain.

Though processing can sometimes wreak havoc on flavor, foodmakers who use yellow corn tortilla flour seem to have lucked out with 2-aminoacetophenone. Instead of being lost in processing, the compound is apparently formed when kernels are steeped in hot lime water. After soaking, kernels are wet-ground to make moist dough. Corn kernels harden on drying cobs, but the lime softens them and makes them easier to grind, notes Buttery.

"In Mexico," he says, "the flour was traditionally used directly to make tortillas. Now it's also dried commercially to make tortilla flour that's convenient to store."

SCOTT BAUER

A key flavor chemical of yellow corn flour has been identified. (K5565-18)

Foods like tortilla chips owe much of their success to the unique, universally accepted flavor of corn flour. Virtually unheard of 30 years ago, tortilla chips today rate higher than microwave popcorn in U.S. snackfood popularity and are second only to potato chips in snack item sales. America's foodmakers market about $2.5 billion worth of tortilla chips each year, according to the Snack Food Association. The average American spends about $10 a year on tortilla chips.

Buttery and Ling analyzed 2-aminoacetophenone and other aroma-imparting chemicals extracted from yellow corn tortilla flour, tortillas, and taco shells purchased at a local supermarket. They used two instruments—a gas chromatograph and mass spectrometer—to identify and measure the compounds.

They enlisted the help of 20 taste panelists to sniff the chemicals and nose out the compounds that give the flour its characteristic grainy aroma. The final aroma ratings that the researchers assigned to 30 chemicals incorporate laboratory analyses and the assessments of the panelists.

The 2-aminoacetophenone compound, with the highest rating, had been overlooked by earlier researchers who analyzed the flour's flavor components. And the Albany team uncovered four other compounds that weren't previously known to enhance the flavor.

The scientists reported their findings earlier this year in the *Journal of Agricultural and Food Chemistry.*—By **Marcia Wood,** ARS.

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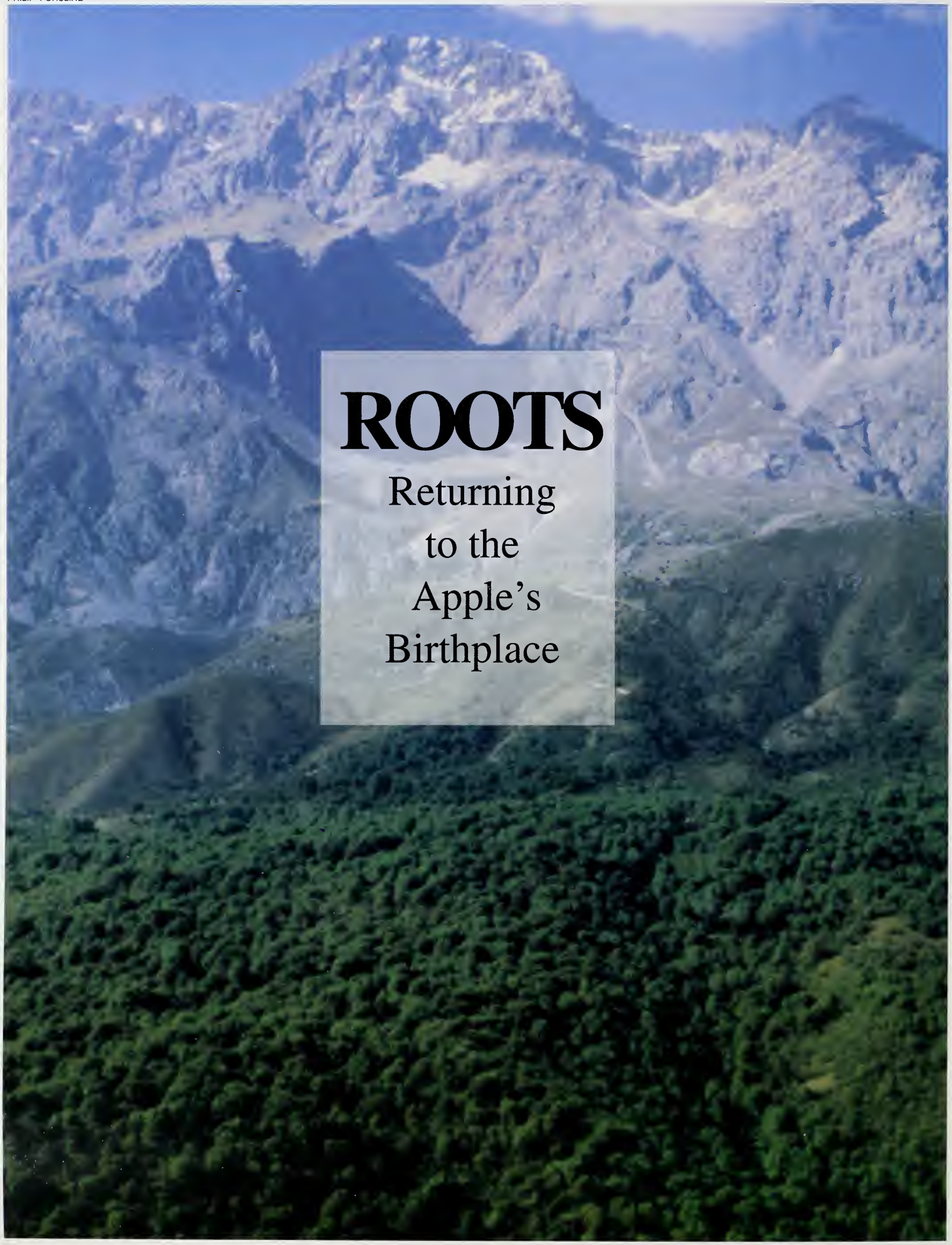
PHILIP FORSLINE



ROOTS

Returning to the Apple's Birthplace

The quest for new apple genes takes ARS plant explorers to Central Asia.

Fritz Wafler has been in the apple business since the 1960's. Today he grows 12 popular varieties—including McIntosh, Jonagold, and Empire—on his 250-acre apple orchard in Wolcott, New York, near Lake Ontario. One of his biggest expenses is the chemicals to control insects and diseases. Pesticides cost him about $200 per acre, per year—an expense he'd rather do without.

"We get a lot of flak for spraying," he says. "Farmers would be the first to admit that they would be happier if they didn't have to spray."

Wafler hopes that eventually he'll be able to grow apples that have genetic resistance to insects and diseases, allowing him to reduce or even eliminate pesticide applications.

The best bet for finding genetic resistance lies in the seeds of the wild apples that Agricultural Research Service scientist Philip L. Forsline and his fellow explorers have found in the mountains of Kazakhstan and Kyrgyzstan.

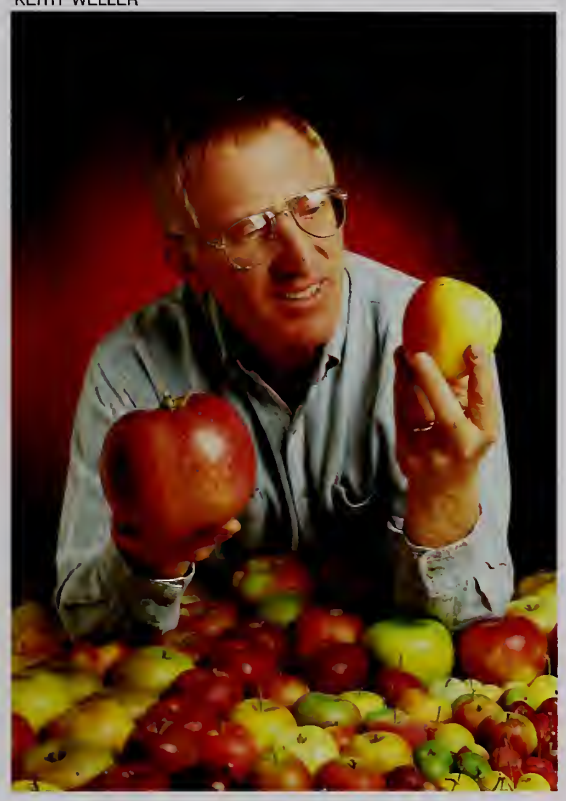
"I really hope the apples they brought back can help us," Wafler says. Forsline is optimistic they will.

In September 1993, he organized and led a collection trip to the two countries in Central Asia. Three other scientists were part of the research team—taxonomist Elizabeth E. Dickson of Cornell University, fruit tree disease expert Gaylord Mink of Washington State University, and breeder Dominique Noiton of Havelock North Research Center in New Zealand. They spent 22 days collecting wild apples in areas where western scientists have never explored before.

Their goal was to scour the rugged foothills for apples in the place where scientists believe the domestic apple *(Malus x domestica)* was born and evolved—its center of origin, as curators say.

The expedition was a follow-up to an earlier trip that Dickson, Cornell plant pathologist Herb Aldwinckle, and ARS botanist Calvin R. Sperling made to neighboring areas in 1989.

KEITH WELLER



Philip Forsline, curator for the apple and grape germplasm at Geneva, New York, displays apples that show the diversity in the collection. The Wolf River in his right hand weighs 20 ounces and measures 4-1/2 inches across. (K5340-9)

The explorations are part of an ongoing effort by scientists with ARS, universities, and other institutions to preserve valuable genes that may otherwise be lost due to neglect, development, or other factors.

The germplasm—usually cuttings or seeds—is housed in storage facilities where it can be saved for use by breeders to improve agricultural crops.

The need to preserve germplasm is immediate, says Forsline, curator for the apple and grape collection of the ARS Plant Genetic Resources Unit at Geneva, New York. In one area of Kazakhstan, near the capital of Almaty, nearly 80 percent of wild fruit forests have disappeared since 1960 because of development. In another area, in Kyrgyzstan, the government has mandated harvesting walnut trees for wood—threatening the diversity of that nut tree.

"We were very fortunate to be able to collect germplasm from these areas, because no one knows how long it will be there," Forsline says.

It's too early to tell how valuable the newly collected apple germplasm is. Some of the seeds from the 1993 trip have been planted and have grown into seedlings, but it can take from 5 to 7 years for them to mature and bear fruit. Forsline says 400 trees are now growing outdoors from seed collected during the 1989 trip. But, in their fourth year, only three of them are fruiting.

"We are confident that we collected apples in remote places that western scientists have probably never explored before," he says. "We think the germplasm will help us widen the genetic base of our collection. Many of the apples we collected are in the wild species *Malus sieversii,* a major genetic contributor to *M. x domestica*."

In 1989, scientists returned with 114 apple samples—called accessions. During the 1993 trip, they collected 129 more, representing 24 crop species—including apples, pears, hawthorn, hops, walnuts, pistachios, and grapes. They brought back 78 cuttings and 33,000 seeds—including 18,000 apple seeds. Some of the seeds have been planted, have grown into seedlings, and are under evaluation by scientists around the country and world, Forsline says.

Preliminary results are encouraging. Aldwinckle, who chairs the Apple Crop Advisory Committee and is evaluating the germplasm in a

The Ferganskiy Range towers above wild apple and walnut forests in the Republic of Kyrgyzstan.

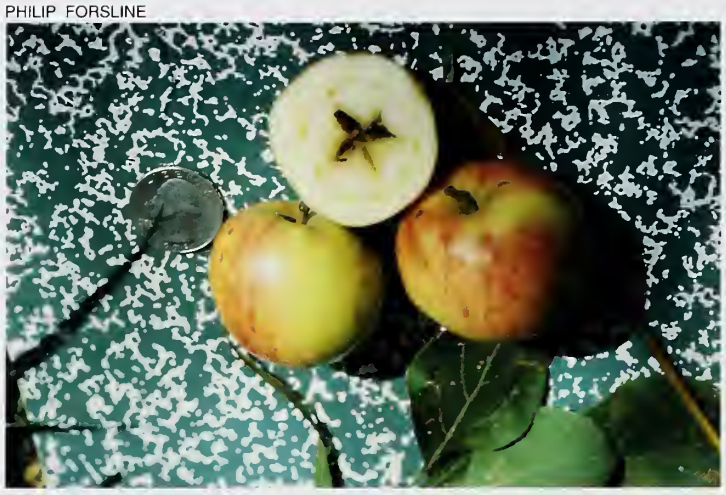
cooperative project with ARS, says some of the seedlings from the 1993 trip have resistance to apple scab, based on early greenhouse studies.

Apple scab, a fungal disease, is among the most serious problems for apple growers, blemishing fruit and causing millions in losses each year.

"Resistant seedlings wouldn't have to be sprayed with fungicides to control the scab," he says.

Aldwinckle says he will also test seedlings from the 1993 trip for resistance to rust, fire blight, and powdery mildew diseases. He says germplasm he has screened from the 1989 trip has resistance to scab, fire blight, and rust. "We think apple germplasm from the two trips will be of great interest to breeders looking for resistance to these diseases," he says.

PHILIP FORSLINE



Collected near Topolevka, Republic of Kazakhstan, this wild apple's superior taste and texture made it one of the highest quality specimens found.

PHILIP FORSLINE

A dry region near Boraldy in Kazakhstan yielded pistachio germplasm for the plant explorers.

Wild Apple Antecedents

The 1989 and 1993 trips probably wouldn't have come about if not for the initial contact between Aldwinckle and Aimak Djangaliev, a professor of Biological Sciences at the Academy of Sciences in Kazakhstan. The 80-year-old Djangaliev has studied the wild apples of Kazakhstan for much of his career and helped arrange the exploration trips. He also came to the United States in 1992 to study apples native to the United States.

Today the United States is one of the world's leading apple producers. In 1993, U.S. apple production was an estimated 10.7 million pounds. But only 4 of 35 known *Malus* species are indigenous to the United States, and the 4 are crabapple types that aren't suitable as eating apples.

Rather, the apples we eat today—Red Delicious, Golden Delicious, McIntosh, for example—and that make up the bulk of U.S. commercial production are fruit immigrants, spread over the last few centuries by people like John Chapman, the legendary "Johnny Appleseed."

Forsline says that ancient explorers traveled through the Kazakhstan region—nestled between China to the east and Russia to the north—along the silk trade routes. They transported not only silk from the Orient to Europe, but also apples. "This is one of the ways that apples are thought to have been spread to other parts of the world," he says.

But Forsline and other researchers say that the traders who carried the apple seeds probably brought only a narrow genetic sampling with them. That could explain why domestic apples grown today in the United States have a fairly narrow genetic base, making them susceptible to scab and other diseases. The typical eating apple of today probably contains genes from only two or three of the known species, Forsline says. "In apple breeding, we've really only scratched the genetic surface, so to speak."

To broaden the apple's genetic base, scientists need to bring in new genes from those areas where apples evolved, for it is there they will find the greatest genetic diversity. And the more out of the way and remote the area, the better the chance of finding rare genes that have never been collected before.

Going off the beaten path had its challenges. Many of the remote mountain areas were accessible only by helicopter, hiking, or by taking a jeep down a dusty road for half a day. Sometimes, Forsline says, they were accompanied by aides carrying rifles to guard against a wild bear or boar that might happen to have its eye on the same apple tree.

On a typical day, the scientists collected between 500 and 1,000 apples. Often the apples were small—only about 1 to 2 inches in diameter—because of old age and environmental stresses such as drought and disease. But the fruit were a variety of colors, sizes, and apple shapes—and some, not surprisingly, looked nearly identical to the

PHILIP FORSLINE

Assisted by Leonid Butenok (center) and his son-in-law, Elizabeth Dickson of Cornell University wraps apple twigs and leaves in paper for shipment from Almaty, Kazakhstan, to the United States. Such herbarium specimens are used by taxonomists to identify different types of apples. Butenok furnished technical assistance during the collection trip.

popular varieties we buy in the local produce section.

"We saw some that looked like Golden Delicious, Red Delicious, and like the New Zealand variety Gala that is becoming popular," Forsline says. "You can see that the genetic base came from that area."

Evenings were spent extracting seed from the apples. This usually took place in a yurt, a circular tent made from animal hides and decorated with Persian rugs. The scientists and their hosts would score the apples around their perimeters, just below equator, and twist the two halves apart so they could extract undamaged seeds. Each apple yielded from 2 to 10, depending on its size and other factors.

When it was time for sleep, they slept in bunkhouses that were built years earlier for Khazakh Ministry of Forestry personnel and others exploring the fruit-filled mountains.

Forsline says there was a flurry of activity in the bunkhouses each night, as rodents scampered around, lured by the smell of the extracted seeds.

To increase the apple germplasm collection's diversity even further, Forsline wants to return to other areas of the region. Perhaps he will go in 1995 or 1996, as part of a 4-year follow-up project on apples with Kazakhstan funded by ARS and USDA's Foreign Agricultural Service. He says a trip to nearby China would also be helpful, since researchers believe the wild apples there may contain useful genetic material as well.

Meanwhile, apple-grower Wafler hopes the potential becomes reality. "This is the future of apples," he says.—By **Sean Adams,** ARS.

Philip L. Forsline is in the USDA-ARS Plant Genetics Resources Unit, Cornell University, Geneva, NY 14456; phone (315) 787-2390, fax (315) 787-2339. ◆

Natural Microbes Curb Salmonella

On-farm treatment could reduce cross-contamination during poultry processing.

In the early months of 1994, on a parched Puerto Rican hillside where golden-eyed goats watched from the sparse shade of grapefruit trees, a new weapon was tested that could positively affect human health worldwide.

The event was a study in incongruities. Instead of a high-tech chrome-and-glass laboratory, the primary testing facilities for this cutting-edge technology were six low-slung gray metal farm buildings where hot breezes swirled dust and feathers.

The weapon itself, designed to stymie salmonella contamination of poultry, was no alchemist's concoction, but a select blend of bacteria that naturally live and prosper in the guts of mature chickens.

And it worked.

"This mixture was successful in controlling environmental salmonella," reports Donald E. Corrier, project leader for salmonella poultry research at ARS' Food Animal Protection Research Laboratory at College Station, Texas.

"We aren't saying this product will lead to cleaner chicken, because there are many variables between when the bird leaves the farm and goes to market," says John R. DeLoach, head of the Food and Feed Safety Research Unit at College Station.

"The objective here is a cleaner chicken at the farm gate. We have to reduce contamination at the farm for the plant to get better."

A Study of Comparisons

The Puerto Rican field tests ultimately focused on three farms, each with two poultry houses. At each farm, chickens in one house were sprayed on arrival with the beneficial bacterial blend, while the birds in the farmer's other poultry house were not treated.

When the chickens were later examined, 21 percent of the untreated birds tested positive for the presence of salmonella on skin and feathers—major sources of salmonella in poultry processing plants—compared with only 8 percent positive in the treated birds, says Corrier.

And when the birds' ceca—two small sacks in the intestines where salmonella tend to lurk—were checked at the processing plant, an average of 2.7 percent of the treated birds showed contamination, less than half of the 5.7 percent contamination found among the untreated birds. This represents a 53-percent reduction in the number of contaminated birds.

The path that led Corrier and coworkers to Puerto Rico's remote Hacienda Hucar began at College Station in 1987 with a young ARS microbiologist named Tony Oyofo.

"Tony thought an important part of salmonella colonization in poultry was the salmonella's ability to attach in the ceca," recalls Corrier.

"Scientific literature said *E. coli* attachment in human kidneys could be blocked with carbohydrates. The bacterium has a special substance on its coating that matches a receptor site in humans, like a key in a lock.

"Tony wanted to see if he could block salmonella attachment in poultry by feeding young birds a sugar called mannose, which has the same configuration that's present on salmonella bacteria. His idea was to use mannose to cover up those intestinal receptors."

Oyofo's idea proved successful in reducing salmonella in chickens. But at about $2.50 per bird, it also proved prohibitively expensive.

So Oyofo and DeLoach switched to less expensive lactose, or milk sugar. In laboratory tests, lactose significantly reduced salmonella colonization in broiler chicks, but its use ultimately led to more questions than answers.

"Lactose worked well for about three experiments, and then it just didn't work," Corrier recalls.

ROBERT DROLESKEY

Poultry house near Salinas, Puerto Rico, was one of six used in cooperative research to reduce salmonella contamination in broilers by treating young birds with intestinal microorganisms from mature chickens.

"We found that for lactose to be effective, the right bacteria had to be present in the bird's intestines to use the lactose."

Pinpointing precisely which bacteria have a taste for lactose was no simple task. So postdoctoral microbiologist David J. Nisbet was hired to tackle the puzzle.

The First Step: Bacterial Brews

Nisbet brewed bacterial mixes from poultry cecal contents, using a technique called Continuous Flow Culture. His first blend fed for 350 days on glucose. This diet eventually pared the bacterial community to only those organisms capable of surviving on that energy source. Then Charles M. Scanlan of Texas A&M University's Department of Veterinary Pathobiology identified the 13 surviving strains, and Nisbet reassembled the mixture as CF-1.

Almost simultaneously, Nisbet started what would become CF-2, this time using as an energy source lactose supplied by a commercial cooperator, Milk Specialties Co. of Dundee, Illinois. [See sidebar.] Scanlan again identified the bacterial survivors; there were 11.

In laboratory tests at College Station, CF-1 and CF-2 were successful at inhibiting salmonella colonization in chicks, but neither system was economical.

"CF-2 worked quite nicely," says Corrier. "We inoculated newly hatched chicks with it, followed by 5 percent lactose in their diet. But lactose costs too much for commercial producers to use this way.

"In tests using CF-1, the chicks got 2 percent lactose, then 10,000 *Salmonella typhimurium* bacteria apiece on day 2 of their life. When we checked them at 10 days of age, we found a consistent 99.9 percent drop in salmonella in their intestinal contents."

But the specter of unacceptable expense still loomed, so the team decided to shoot for a bacterial blend requiring no lactose. The result—a combination of 29 organisms taken from three mature broilers—became CF-3. In laboratory tests, day-old chicks were dosed with CF-3, followed the next day by 10,000 *S. typhimurium* apiece. After 10 days, the chicks' cecal contents were analyzed.

ROBERT DROLESKEY

Veterinary pathologist Don Corrier gathers samples of poultry litter to check levels of salmonella bacteria in the poultry house.

"CF-3 also reduced salmonella in the ceca by 99.9 percent," reports Corrier. "And, the number of salmonella per gram of cecal content went from a million to less than 10 per gram." In follow-up laboratory tests, CF-3 shone every time.

Providing invaluable assistance—ranging from birds and space to salmonella expertise—was USDA collaborator Billy M. Hargis, another member of Texas A&M's veterinary pathobiology faculty.

"What makes CF-3 novel," Hargis says, "is that we know what microorganisms are in the culture. A lot of people have shown you can take cecal contents, dry them, grind them up, give them to baby chicks, and get protection.

" But there is the possibility of pathogens in that mix. And just as you can prevent disease, you can also cause it. This CF-3 culture contains only those bacteria we want."

A New Approach Emerges

Gradually, the initial concept of mannose covering up crucial intestinal receptors was replaced by another idea: that nature provides its own defenses against salmonella in a mature chicken but could use a little boost.

"Other scientists have shown that volatile fatty acids such as propionic acid don't kill salmonella in a chicken, but they do inhibit its growth," Corrier points out. "We found that 80 percent of the time, we can link increased propionic acid in 10-day-old birds with control of salmonella growth."

By comparison, a 3-day-old chick does not have enough volatile fatty acids to fend off salmonella—unless the chick is lucky enough to have been treated to the Texas team's bacterial brew.

"The cecal environment of a 3-day-old bird treated with CF-3 is similar to the natural cecal environment of a 21-day-old bird," says David Nisbet. "At that point, it's tough for salmonella to get established."

Still, as any scientist can testify, much can go awry between the promising laboratory results and the harsh reality of the field. When Corrier and his team sought to follow up with field tests, their first problem was finding a commercial partner.

Happily, a candidate soon emerged: Industrias Avicolas de Puerto Rico, Inc., whose busty little *Pollo Picú* ("cute chicken") symbol adorns poultry products ranging from parts to whole birds and sausages in Puerto Rican groceries.

Headquartered in picturesque Coamo, Puerto Rico, where pastel houses and palm fronds crowd the narrow streets, Picú—as the company is widely known—has a long history of cooperating with federal inspectors on projects aimed at producing a cleaner product. So when John DeLoach contacted Picú in 1989 about working on the salmonella project, corporate support went all the way to the top.

"Salmonella is a problem in this industry," says Antonio Alvarez, Picú's president and one of its founders. "We think if we work together on this, we can benefit from it. We figure we should have as clean an industry as possible."

Corrier's team needed poultry houses where treated and untreated broilers could be compared—from chick delivery to processing plant. Picú had plenty to choose from: The company has 176 poultry producers under contract, each typically operating two poultry houses capable of holding 10,000 to 15,000 birds apiece to fuel the stream of about 66 million pounds of meat emerging annually from Picú's processing plant.

The Puerto Rican poultry industry dates only to the mid-1950's, finding its feet under the direction of former high school principal Stanley L. Miller. But it's a healthy youngster.

Puerto Rican producers in 1993 turned out 122 million pounds of poultry, all consumed on the island. In addition, 165 million pounds of imported chicken are dished up in forms ranging from delectable *chicharrons de pollo* (chunks of fried skin and meat) to whole barbecued chickens glistening in glass cases outside roadside cantinas.

When Miller founded one of the island's top poultry companies, To-Rico, in 1958, young Antonio Alvarez went to work with him, armed with a biology degree from Indiana's Goshen College.

To-Rico was also a strong supporter of *La Polluelos,* "The Baby Chicks," an Aibonito-based baseball team, so Alvarez labored in left field for 8 years. When he gave up his glove, he persuaded the team to take on a promising youngster named José Cruz, who later burned up the bases for the major-league Houston Astros. In all, Alvarez says, *La Polluelos* sent five players to the majors; Alvarez himself was named to Puerto Rico's Amateur Baseball Hall of Fame in 1985.

By that time, Alvarez was at the helm of Picú, which he started with a group of friends and an unusual strategy—reserving a sizable chunk of company stock for the growers themselves. Impressed by the entrepreneurs' plans, the Puerto Rican agriculture department bought large pieces of land on the island and divided them into smaller holdings that were sold to people willing to try their hand at chicken farming.

Several grower communities were established, including Hacienda Hucar, a complex of 30 farms where new neighbors helped build each others' homes. Although many of the new farmers had to attend classes on how to grow chickens, the first Picú bird was processed on November 1, 1977, with the governor of Puerto Rico pushing the button to start the line. Today, Picú sends 140 birds a minute down its stainless steel processing lines.

An integral player in the salmonella project has been Picú veterinarian Luis M. Vidal, who works with the Hucar growers. Vidal smoothed the way for tests to begin on Hucar farms in 1992 and says the growers welcome any advances that increase their chances of success.

ROBERT DROLESKEY

Billy Hargis (left), with Texas A&M, and ARS biochemist John DeLoach prepare a chicken intestine for examination.

"The Hucar is one of the hottest areas of the island," he notes. "If the electricity for your fans goes out, you can lose a thousand chickens in one day. But the growers feel great about this project; they're making a good living growing the chickens, and think this project will benefit them and the industry."

The Texas team—DeLoach, Corrier, Scanlan, Nisbet, and Hargis, plus ARS technicians Clayton J. Myers and James D. Snodgrass, ARS microbiologist Albert G. Hollister, and ARS biologist Robert E. Drolesky—came to know well the sizzling heat at Hacienda Hucar, which lies on the wrong side of the Cordillera Central mountain range to enjoy the lush rains of the island's northern side.

On-Farm Testing

In long months of environmental sampling, team members found 29 different salmonella serotypes on the Hucar farms, with three—*Salmonella hadar*, *S. derby*, and *S. kentucky*—accounting for 40 percent.

As the last name suggests, all these salmonella serotypes are found on U.S. poultry farms as well.

"What we see here is representative of what you see in the mainland United States," says DeLoach.

Finally, flock testing began on the selected farms of Francisco Torres Rosario, Ariel Santiago, and Wilfredo Colon. On a typical test day in mid-April, the research team was on the road before sunrise, hoping to beat the heat that even in early spring made only the mornings bearable.

At the farm designated for that day, workers donned white plastic jumpsuits, booties, gloves, hairnets, and face masks before entering the poultry houses. One team was dispatched to a house filled with CF-3 treated birds; the other worked with the farm's untreated chickens.

ROBERT DROLESKEY

Technician Carol Thomas makes agar plates for bacterial samples that will be grown to check for the presence of salmonella.

Multiple samples of litter, water, and feed were taken to determine salmonella levels. Then, in each house, 105 birds were randomly selected, killed, and double-bagged. By 7:30 a.m., workers' faces were deeply flushed and sweat flowed, but the masks stayed in place as the sea of startled chickens flapped the house's air into a palpable cloud of dust and feathers.

If chickens could get used to anything, they should have been used to the workers by mid-April; the same sort of drill had been undertaken on each of the three farms at regular intervals since early March.

But the poultry house proceedings were only the beginning. Next, the team and their collected birds bounced down dirt roads to the Hucar community center, a beige one-room structure with metal-louvered open windows and three rough wooden benches.

There, birds were weighed and then, one by one, all 210 were divested of a small triangle of chest skin and feathers and then eviscerated, their ceca snipped into odiferous chunks in small plastic tubes, a process quickly described but stretching on for hours. The sealed tubes were packed on ice and on their way that afternoon back to Texas for analysis by a team headed by techni-

cians Kate Andrews of ARS and David J. Caldwell of Texas A&M.

"Ceca are reservoirs of salmonella in the birds," explains Texas A&M's Hargis. "The ceca empty only once a day, and since they're blind sacks, the salmonella settle there and don't get flushed out as fast."

In the final phase of the project, treated and untreated birds were run through Picú's processing plant at Coamo and more samples were taken to check salmonella levels.

Eventually, says Hargis, natural methods of combating disease microorganisms in poultry could lessen the now common addition of antibiotics to poultry feed.

"The number of antibiotics available for therapeutic use in chickens is decreasing because of human health concerns," he points out.

"I think this culture is just the beginning as far as an alternative. This or similar cultures might be effective against listeria, campylobacter, or *E. coli*. To some extent in the future, I think we may be able to replace antibiotics with this sort of competitive exclusion."—By **Sandy Miller Hays**, ARS.

Scientists mentioned in this article can be reached by contacting the USDA-ARS Food Animal Protection Research Laboratory, 2881 F&B Road, College Station, TX 77845; phone (409) 260-9484, fax (409) 260-9332. ◆

Top: In this section of chicken intestine (magnified about 170 times), treatment with CF-3 has allowed harmless bacteria to proliferate. The bacteria exclude salmonella organisms by covering most of the sites where they can attach. Bottom: Intestine from an untreated chicken showing many sites available for salmonella.

The Search for Alternatives

When ARS scientists at College Station, Texas, first envisioned lactose—milk sugar—as a prime weapon in the war against salmonella in poultry, it seemed a match made in heaven when Milk Specialties Co. offered to help.

After all, the 50-year-old firm headquartered in Dundee, Illinois, made its living selling bovine products ranging from livestock feed ingredients to rawhide chews. Milk Specialties entered a cooperative research and development agreement with ARS and kept the scientists supplied with lactose for the salmonella experiments.

Then came a startling finding: "It became obvious that lactose was *not* a key ingredient in blocking salmonella," recalls Trevor Tomkins, vice president of research and quality assurance at Milk Specialties.

Far from losing interest, Milk Specialties continued its support and has obtained an exclusive license for ARS' bacterial blend dubbed CF-3.

"This fits right in line with our corporate strategy to develop and bring new technology to market, particularly in the areas of nutrition and health," explains Tomkins. "When an organization is trying to be entrepreneurial, you must move where the opportunities take you. Our charter is not just to build a better feed; we're in specialty and unique products, and this fits.

"This technology is just the tip of the iceberg as far as understanding the complexities of flora in the chicken's gut," Tomkins says.

"As we understand more of that, we'll find we can ultimately control enteric diseases in a whole variety of species. I think we have the start here of a mechanism to move away from the use of antibiotics in food animals."—By **Sandy Miller Hays,** ARS.

Science Update

Lure Sought for Tiger Mosquito

ARS and Florida's Department of Agriculture and Consumer Services have entered into a cooperative R&D agreement to combat Asian tiger mosquitoes. These pests, *Aedes albopictus,* invaded about 1986. They can transmit encephalitis, dengue, and other viral diseases of humans. The scientists' aim is to isolate and identify compounds that attract the female insect. Synthetic attractants could help monitor populations of tiger mosquitoes and lure them into contact with natural pathogens to kill them. Tiger mosquitoes, now in 24 states, breed in standing water in old tires, bird baths, and other containers. *Daniel L. Kline, USDA-ARS Medical and Veterinary Entomology Research Laboratory, Gainesville, Florida; phone (904) 374-5933.*

Natural Chemicals Hit Pesky Weeds and Fungi

Natural compounds from two microorganisms may be turned into environmentally friendly foes of crop-pestering fungi and weeds. In ARS studies, *Bacillus subtilis* bacteria churned out iturin, which attacks destructive *Fusarium* and *Aspergillus* fungi.

A different fungus, *Alternaria alternata,* may be a good guy. It makes tentoxin, which meddles with cell growth in most soybean weeds and in johnsongrass in corn. In tests, tentoxin had no ill effect on soybean or corn plants. The next step: find economical ways to produce iturin and tentoxin as alternatives to chemical pesticides. *Alan Lax, USDA-ARS Environmental Technology Research Unit, Southern Regional Research Center, New Orleans, Louisiana; phone (504) 286-4382.*

Pumping Iron at 80 and Up

With high-intensity weight training, many of the 2 million elderly people living in nursing homes could counter muscle weakness, physical frailty, and falls, according to a study funded by ARS and the National Institute on Aging. Volunteers were 100 nursing home residents in their 80's and 90's. By doubling their leg muscle strength in just 10 weeks of training, they could walk faster and climb stairs more easily and were more physically active in general. *Maria Fiatarone, USDA-ARS Human Nutrition Research Center on Aging at Tufts, Boston, Massachusetts; phone (617) 556-3075.*

May Pransky, 98, a resident of the Hebrew Rehabilitation Center for the Aged in Boston, works out on a leg-strengthening machine, while fitness coordinator Evelyn O'Neil looks on. (K5690-1)

Test for Saline or Sodic Soils To Be Commercialized

ARS has a cooperative R&D agreement with the Hach Company in Loveland, Colorado, to devise a rapid new lab test to check soil for two conditions that can drastically cut crop yields. Currently, time-consuming chemical tests are needed to evaluate soil for high salt levels or for high sodicity—a combination of high sodium, low salinity, and high pH. ARS scientists are developing a fast test based on electrical measurements such as soil conductivity. *James D. Rhoades, USDA-ARS U.S. Salinity Laboratory, Riverside, California; phone (909) 369-4814.*

Beneficial Mite Makes Right for the Gorse

A tiny mite has begun tackling a thorny problem—gorse thickets on Pacific Coast pastures, dunes, and hiking trails. ARS scientists raised gorse spider mites, *Tetranychus lintearius,* that were released last summer for the first time in the United States—at sites in Oregon and California. Costly to ranchers, gorse can form nearly impenetrable thickets that crowd out forage plants or block livestock from getting to them. Penpoint-size, rust-colored mites suck the contents of gorse plant cells. But they don't nip other plants, animals, or people—unlike gorse, which pricks hikers and campers with its thorns. Both mite and gorse are native to western Europe. *Charles E. Turner, USDA-ARS Plant Protection Research Unit, Western Regional Research Center, Albany, California; phone (510) 559-5975.*

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Upcoming in the December Issue

- When the signal comes up from the valley that the enemy is on the move, ARS scientists move in with computer-equipped vans, radar, weather balloons, and aircraft to track the invading corn earworms.

- Biocontrol wasps use sonar to detect their corn earworm and fall armyworm prey buried up to 2 inches in the soil.

- ARS scientists are helping hundreds of Native Americans fight to keep weedy invaders off their land. In Montana alone, nine noxious weeds already infest nearly 600,000 acres of Indian Trust lands.